P986: Intensity-Frontier Antiproton Physics with The Antiproton Annihilation Spectrometer (TAPAS) at Fermilab

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Physics Advisory Committee
Fermilab
Batavia, IL
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Outline

(Varied menu!)

- Antiproton sources
- Hyperon CP violation
- A new experiment
- Issues in charmonium
- Charm mixing & CPV
- Impact and cost
- Summary

Antiproton Sources

- Fermilab Antiproton Source is world's most intense (and highest-energy)

Table 1: Antiproton energies and intensities at existing and future facilities.

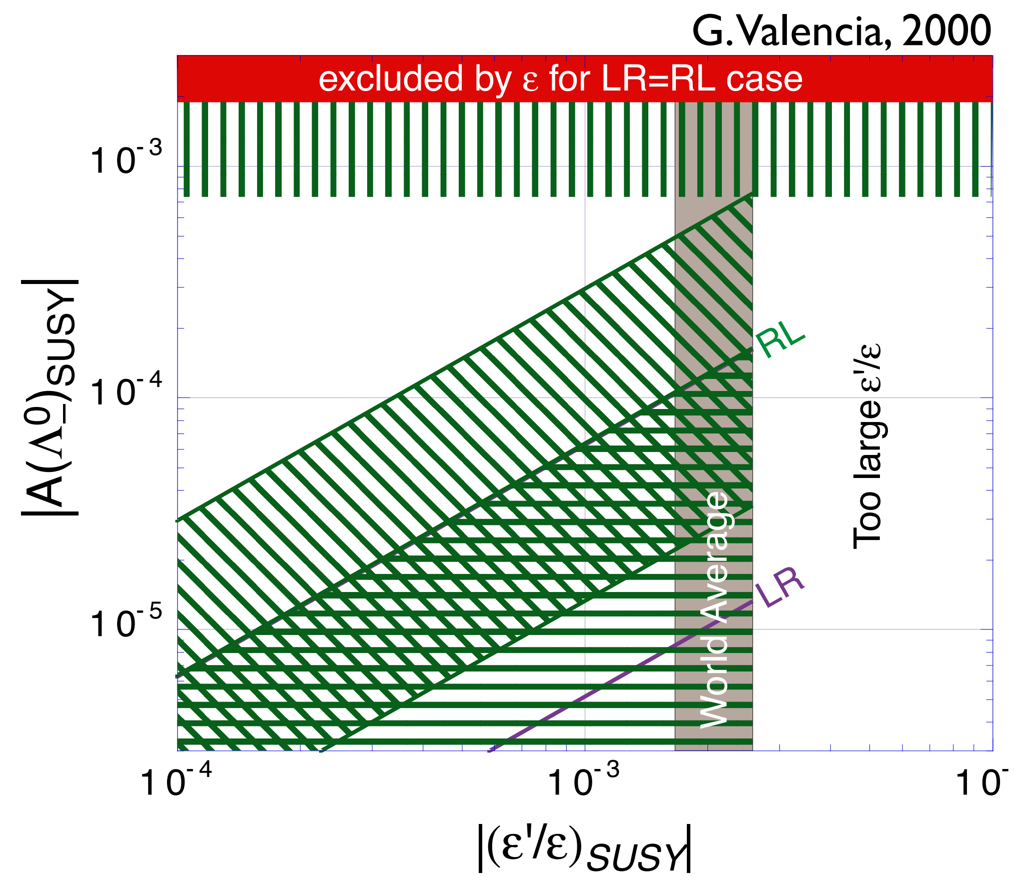
Facility	$\overline{p}$ Kinetic Energy (GeV)	Stacking: Rate (10^{10}/hr)	Stacking: Duty Factor	Operation: Hours /yr	Operation: $\overline{p}$/yr (10^{13})
CERN AD	0.005 0.047	–	–	3800	0.4
Fermilab Accumulator:					
current operation	8	>25	90%	5550	>150
proposed here	≈ 3.5–8	20	15%	5550	17
FAIR ($\gtrsim 2018$*)	1–14	3.5	15%*	2780*	1.5

...even after GSI FAIR turns on (has yet to break ground)

Hyperon CP Violation

- Differently sensitive to new physics than *B* CPV, ε′/ε (parity-*conserving* interactions)
  - complementary to mu2e
- B factories have shown *B* mixing & CPV dominantly SM

⇒ worth looking elsewhere!



- Leading potential signals are A_Λ, $A_{\Xi\Lambda}$, B_Ξ, Δ_Ω:

$$A \equiv \frac{\alpha_\Lambda + \overline{\alpha}_\Lambda}{\alpha_\Lambda - \overline{\alpha}_\Lambda}, \quad B \equiv \frac{\beta_\Lambda + \overline{\beta}_\Lambda}{\beta_\Lambda - \overline{\beta}_\Lambda}, \quad \Delta \equiv \frac{\Gamma_{\Lambda\to p\pi} - \overline{\Gamma}_{\Lambda\to p\pi}}{\Gamma_{\Lambda\to p\pi} + \overline{\Gamma}_{\Lambda\to p\pi}}$$

CP-odd

- $\overline{p}$ source can produce ~10^8 $\Omega^- \overline{\Omega}^+$, & maybe ~$10^{10}$ $\Xi^- \overline{\Xi}^+$ (transition crossing)

Hyperon CP Violation

- SM predicts small CP asymmetries in hyperon decay
- NP can amplify them by orders of magnitude:

Table 5: Summary of predicted hyperon CP asymmetries.

Asymm.	Mode	SM	NP	Ref.
A_Λ	$\Lambda \to p\pi$	$\lesssim 10^{-5}$	$\lesssim 6 \times 10^{-4}$	[68]
$A_{\Xi\Lambda}$	$\Xi^\mp \to \Lambda\pi,\ \Lambda \to p\pi$	$\lesssim 0.5 \times 10^{-4}$	$\leq 1.9 \times 10^{-3}$	[69]
$A_{\Omega\Lambda}$	$\Omega \to \Lambda K,\ \Lambda \to p\pi$	$\leq 4 \times 10^{-5}$	$\leq 8 \times 10^{-3}$	[36]
$\Delta_{\Xi\pi}$	$\Omega \to \Xi^0\pi$	2×10^{-5}	$\leq 2 \times 10^{-4}\,*$	[35]
$\Delta_{\Lambda K}$	$\Omega \to \Lambda K$	$\leq 1 \times 10^{-5}$	$\leq 1 \times 10^{-3}$	[36]

*Once they are taken into account, large final-state interactions may increase this prediction [56].

Hyperon CP Violation

- Measurement history:

Experiment	Decay Mode	A_Λ	
R608 at ISR	$pp \to \Lambda X, \bar{p}p \to \bar{\Lambda} X$	**-0.02 $\pm$ 0.14**	[P. Chauvat et al., PL 163B (1985) 273]
DM2 at Orsay	$e^+e^- \to J/\Psi \to \Lambda\bar{\Lambda}$	**0.01 $\pm$ 0.10**	[M.H. Tixier et al., PL B212 (1988) 523]
PS185 at LEAR	$p\bar{p} \to \Lambda\bar{\Lambda}$	**0.006 $\pm$ 0.015**	[P.D. Barnes et al., NP B 56A (1997) 46]

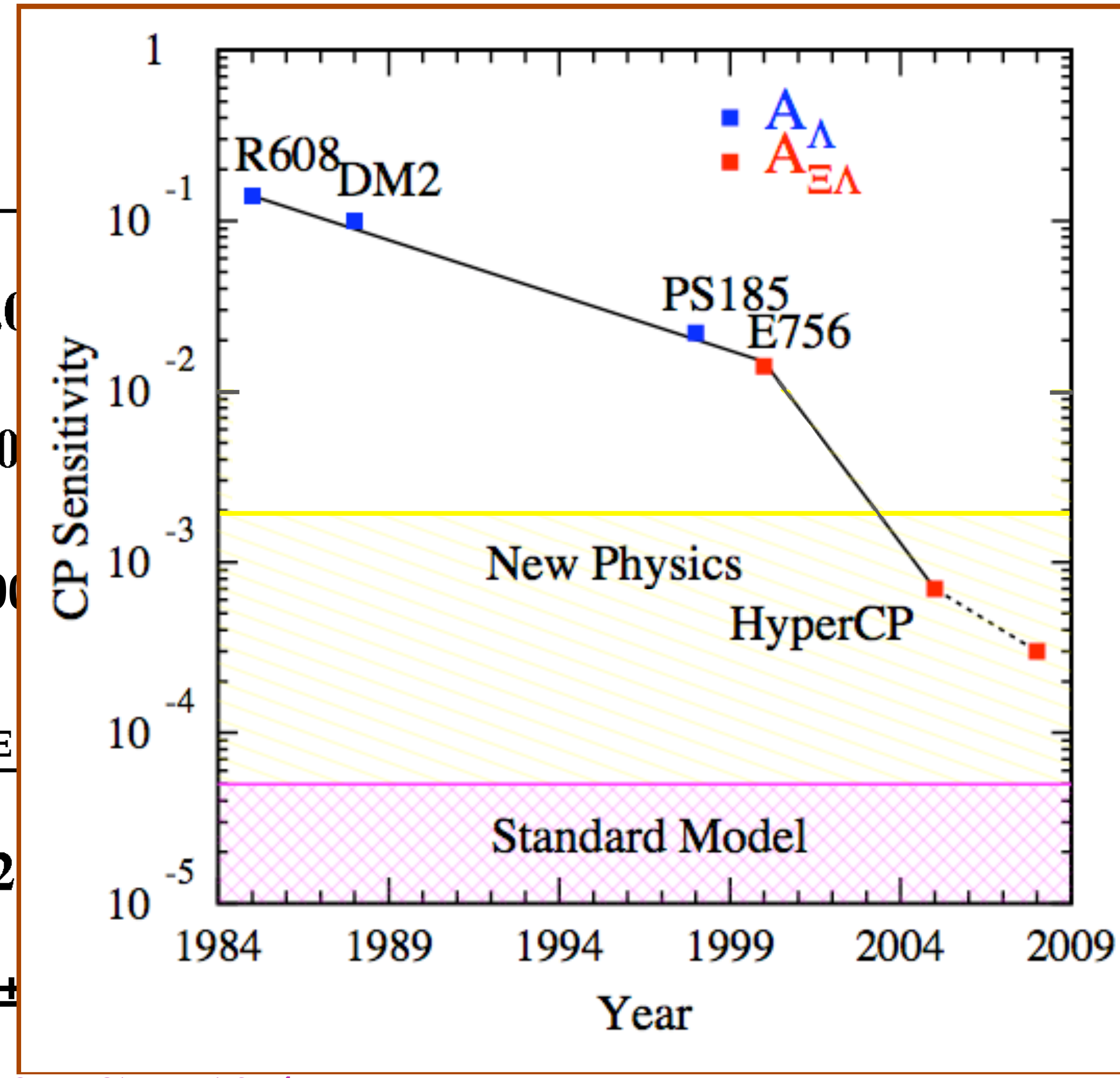
Experiment	Decay Mode	$A_\Xi + A_\Lambda$	
E756 at Fermilab	$\Xi \to \Lambda\pi, \Lambda \to p\pi$	**0.012 $\pm$ 0.014**	[K.B. Luk et al., PRL 85, 4860 (2000)]
E871 at Fermilab (HyperCP)	$\Xi \to \Lambda\pi, \Lambda \to p\pi$	**$(0.0 \pm 6.7) \times 10^{-4}$**	[T. Holmstrom et al., PRL 93. 262001 (2004)]
		$(-6 \pm 2 \pm 2) \times 10^{-4}$	[BEACH08 preliminary; PRL in prep]

Hyperon CP Violation

- Measurement history:

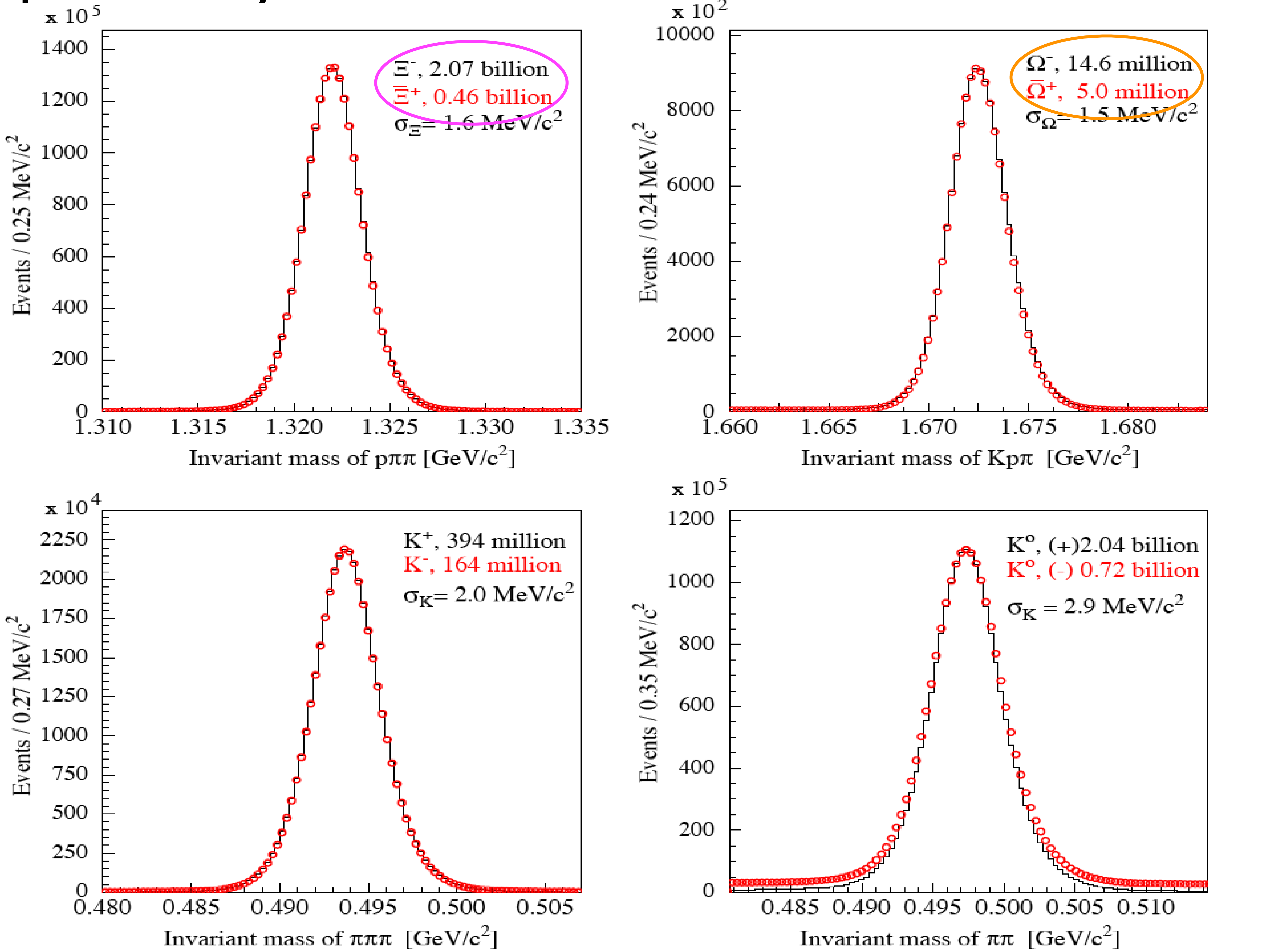
Experiment	Decay Mode	
R608 at ISR	$pp \rightarrow \Lambda X, \bar{p}p \rightarrow \bar{\Lambda} X$	-0.0
DM2 at Orsay	$e^+e^- \rightarrow J/\Psi \rightarrow \Lambda\bar{\Lambda}$	0.0
PS185 at LEAR	$p\bar{p} \rightarrow \Lambda\bar{\Lambda}$	0.00

Experiment	Decay Mode	A_Ξ
E756 at Fermilab	$\Xi \rightarrow \Lambda\pi, \Lambda \rightarrow p\pi$	0.012
E871 at Fermilab (HyperCP)	$\Xi \rightarrow \Lambda\pi, \Lambda \rightarrow p\pi$	(0.0 ±



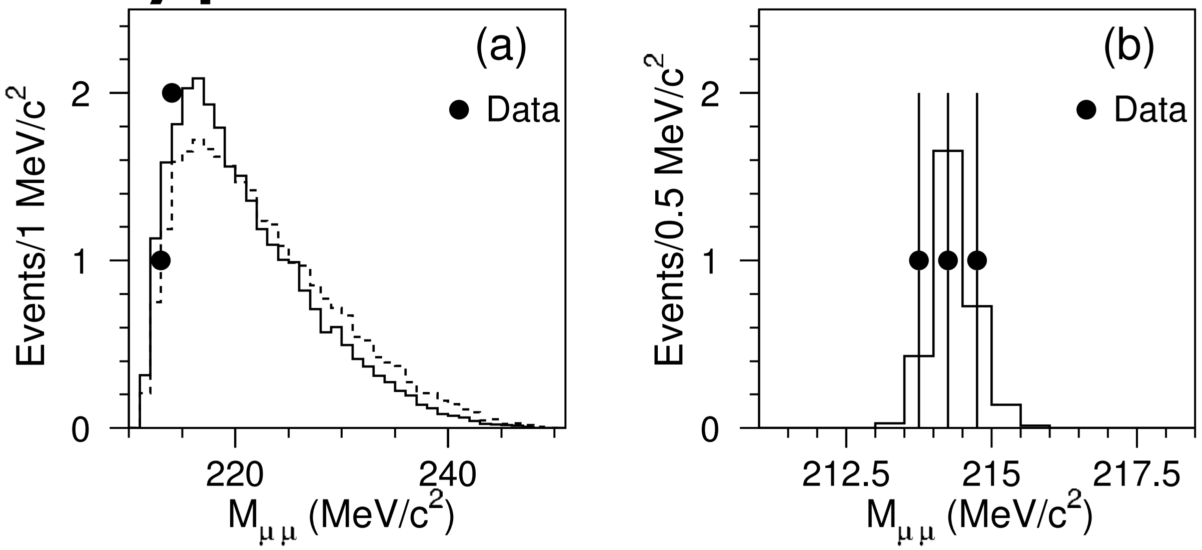
$(-6 \pm 2 \pm 2) \times 10^{-4}$ [BEACH08 preliminary; PRL in prep]

Made possible by... Enormous HyperCP Dataset

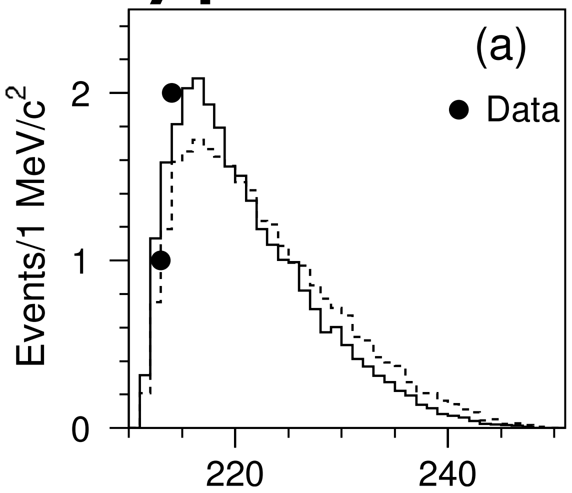


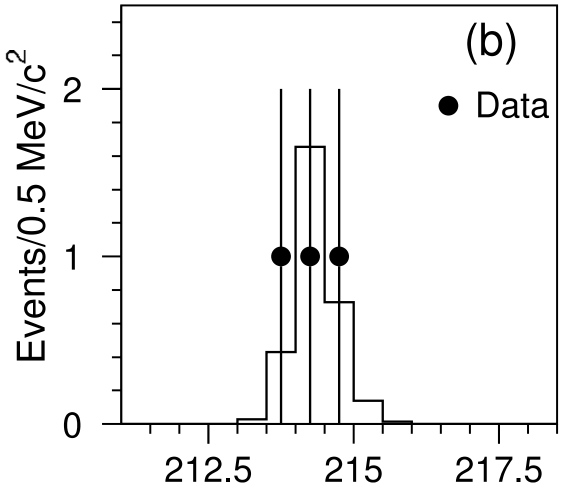
- $\bar{p}$ source can produce ~10^8 $\Omega^-\overline{\Omega}^+$/y (+ ~$10^{10}$ $\Xi^-\overline{\Xi}^+$?)

HyperCP also → 10^{10} Σ^+ $\Sigma^+ \rightarrow p\mu^+\mu^-$ Decay



HyperCP also → 10^{10} Σ^+





$\Sigma^+ \to p\mu^+\mu^-$ Decay

≈2.4σ fluctuation of SM? or

- SUSY Sgoldstino?
- SUSY light Higgs?
- other pseudo-scalar or axial-vector state?

PRL **98,** 081802 (2007) PHYSICAL REVIEW LETTERS week ending 23 FEBRUARY 2007

Does the HyperCP Evidence for the Decay $\Sigma^+ \to p\mu^+\mu^-$ Indicate a Light Pseudoscalar Higgs Boson?

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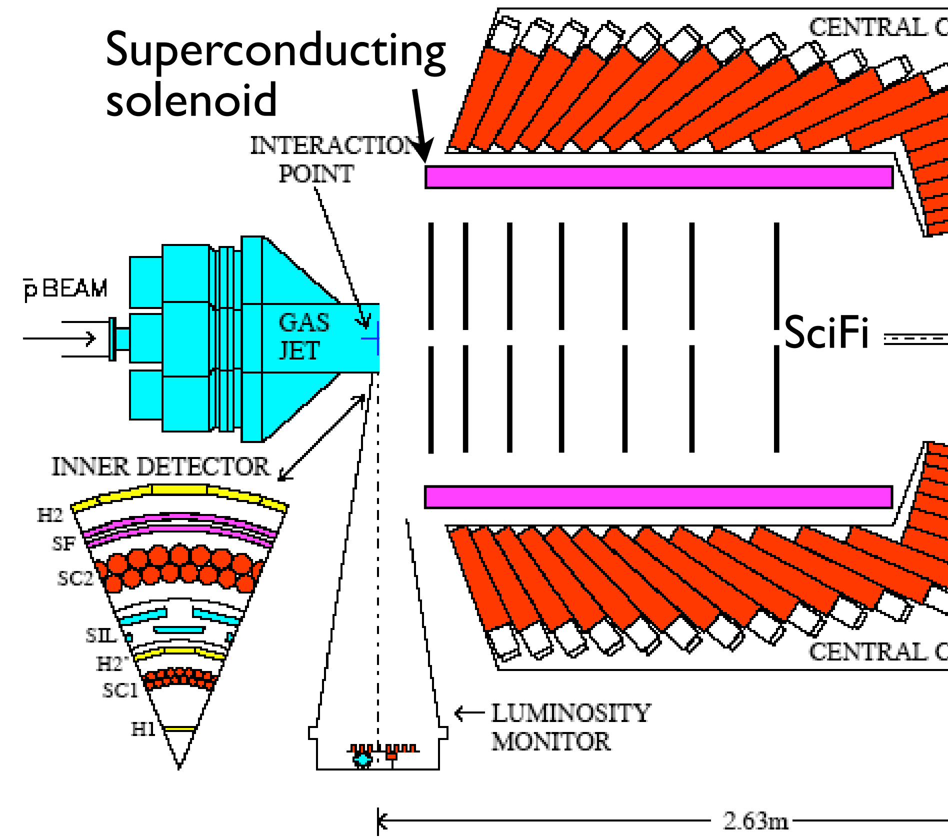
The HyperCP Collaboration has observed three events for the decay $\Sigma^+ \to p\mu^+\mu^-$ which may be interpreted as a new particle of mass 214.3 MeV. However, existing data from kaon and B-meson decays provide stringent constraints on the construction of models that support this interpretation. In this Letter we show that the "HyperCP particle" can be identified with the light pseudoscalar Higgs boson in the next-to-minimal supersymmetric standard model, the A_1^0. In this model there are regions of parameter space where the A_1^0 can satisfy all the existing constraints from kaon and B-meson decays and mediate $\Sigma^+ \to p\mu^+\mu^-$ at a level consistent with the HyperCP observation.

How Follow Up?

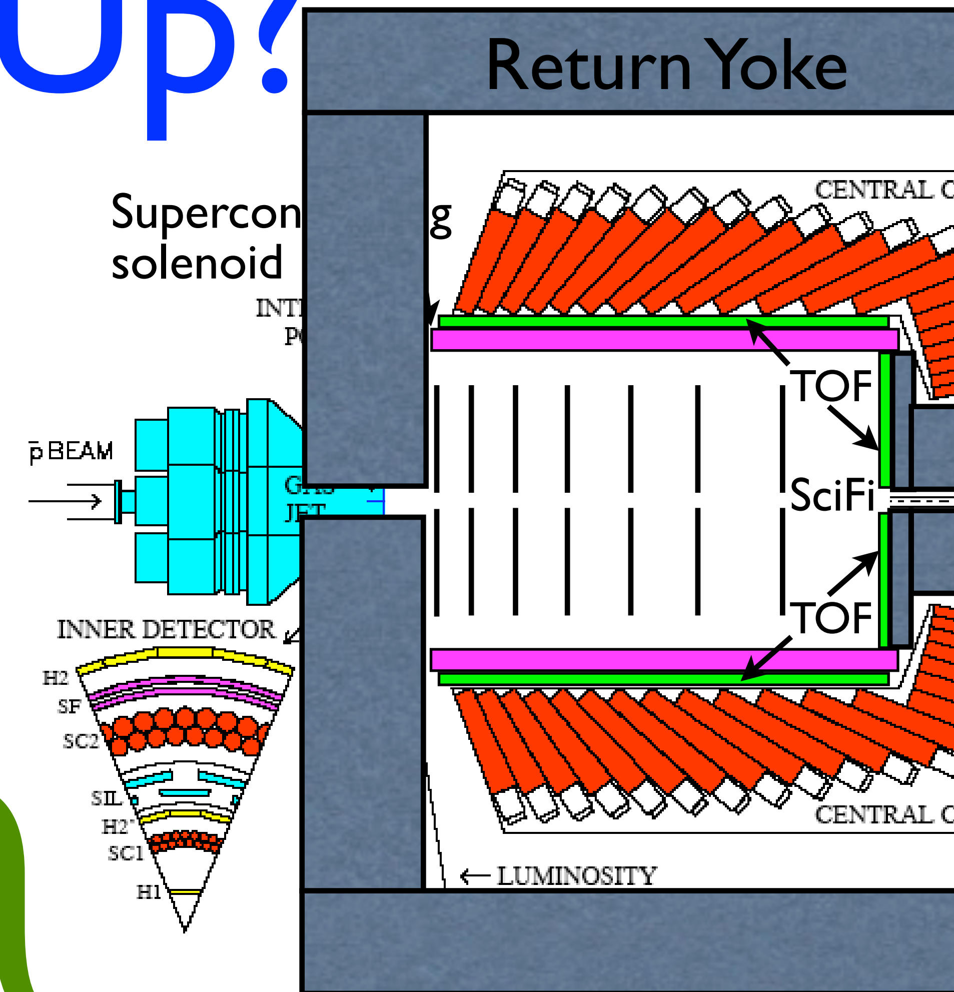
Our proposal:

- After Tevatron finishes,
  - Reinstall E760 barrel calorimeter
  - Add small magnetic spectrometer

[existing BESS magnet from KEK & SciFi DAQ from DØ



How Follow Up?



Our proposal:

- After Tevatron finishes,
  - Reinstall E760 barrel calorimeter
  - Add small magnetic spectrometer
  - Add precision TOF system
  - Add thin targets
  - Add fast trigger & DAQ systems
  - Run $p_{\bar{p}}$ = 5.4 GeV/c ($2m_\Omega < \sqrt{s} < 2m_\Omega + m_{\pi^0}$) @ $\mathcal{L} \sim 10^{32}$ cm^{-2} s^{-1} (10 × E835)

[existing BESS magnet from KEK & SciFi DAQ from DØ & FNAL iron]

<$10M

➡ ~10^8 $\Omega^-\,\overline{\Omega}^+$/yr + ~$10^{12}$ inclusive hyperon events!

+ possibly ~10^{10} $\Xi^-\,\overline{\Xi}^+$

What Can This Do?

- Observe many more $\Sigma^+ \to p\mu^+\mu^-$ events and confirm or refute SUSY interpretation

- Discover or limit $\Omega^- \to \Xi^-\mu^+\mu^-$ and confirm or refute SUSY interpretation

Predicted $\mathcal{B} \sim 10^{-6}$ if P^0 real

- Discover or limit *CP* violation in $\Omega^- \to \Lambda K^-$ and $\Omega^- \to \Xi^0\pi^-$ via partial-rate asymmetries

Predicted $\Delta\mathcal{B} \sim 10^{-5}$ in SM, $\lesssim 10^{-3}$ if NP

What Else Can This Do?

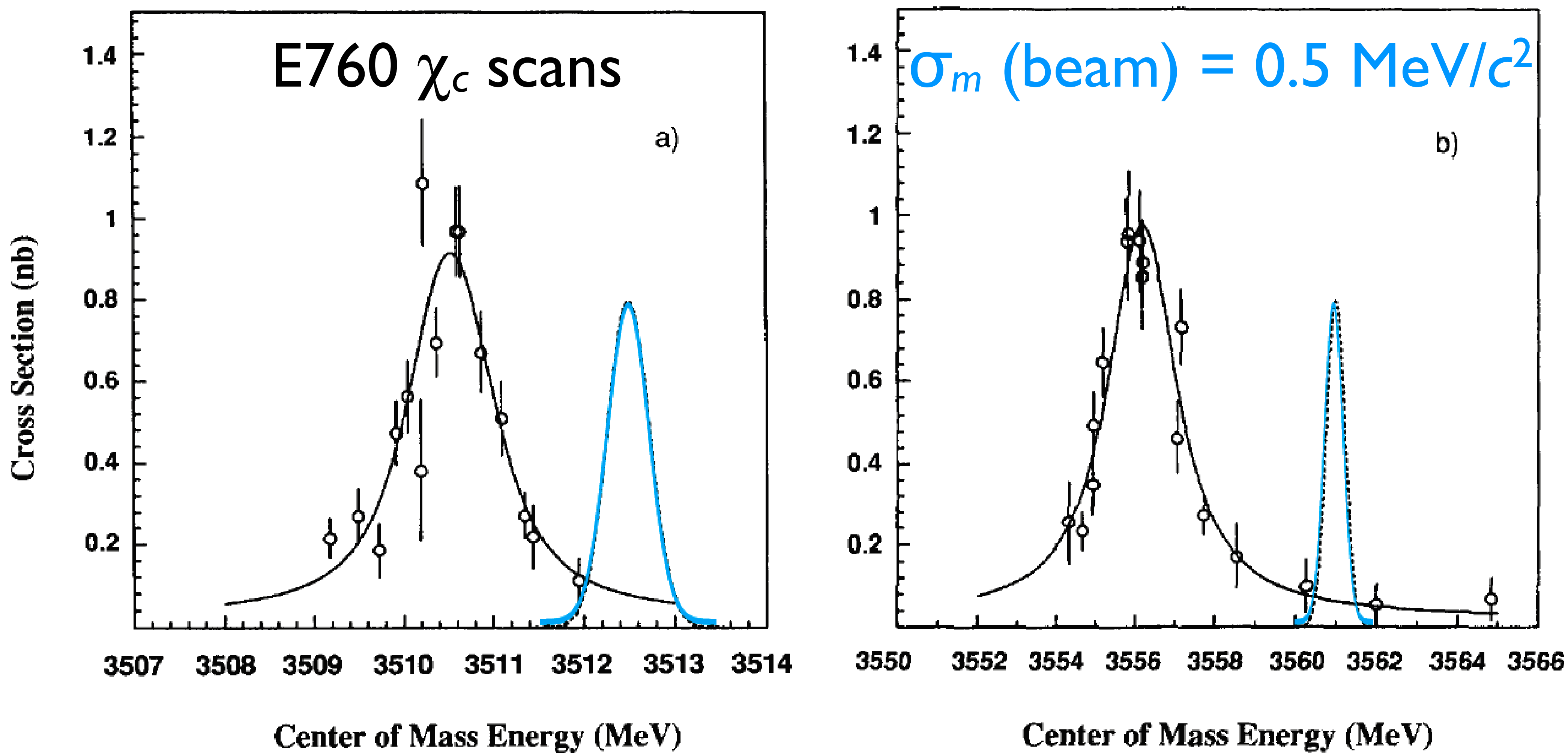
- Much interest lately in new states observed in charmonium region: $X(3872)$, $X(3940)$, $Y(3940)$, $Y(4260)$, and $Z(3930)$
- $X(3872)$ of particular interest: may be the first meson-antimeson ($D^0\,\overline{D}^{*0}$ + c.c.) molecule (or tetraquark or what?)

➡ need *very* precise mass & width measurement to confirm or refute

➡ $\bar{p}p \to X(3872)$ formation *ideal* for this

- Also h_c mass & width, χ_c radiative-decay angular distributions, $\eta_c{}'$ full and radiative widths,...

Example: precision $\bar{p}p$ mass & width measurements



- The beam is the spectrometer! $\rightarrow \begin{cases} \delta m(\chi_c) \approx 0.1 \pm 0.02 \text{ MeV}/c^2 \\ \delta\Gamma(\chi_c) \approx 0.1 \pm 0.01 \text{ MeV}/c^2 \end{cases}$
- The experiment is just the detector.

Example: precision $\bar{p}p$ mass & width measurements

- Works even for ψ′:
  - E835 measured
    Γ = (290 ± 25 ± 4) keV
    with 2,700 events
  - used "complementary scans" to reduce systematics

⇒Best technique for $X(3872)$ mass, (sub-MeV?) width, & line-shape measurement

Andreotti et al., PLB654 (2007) 74

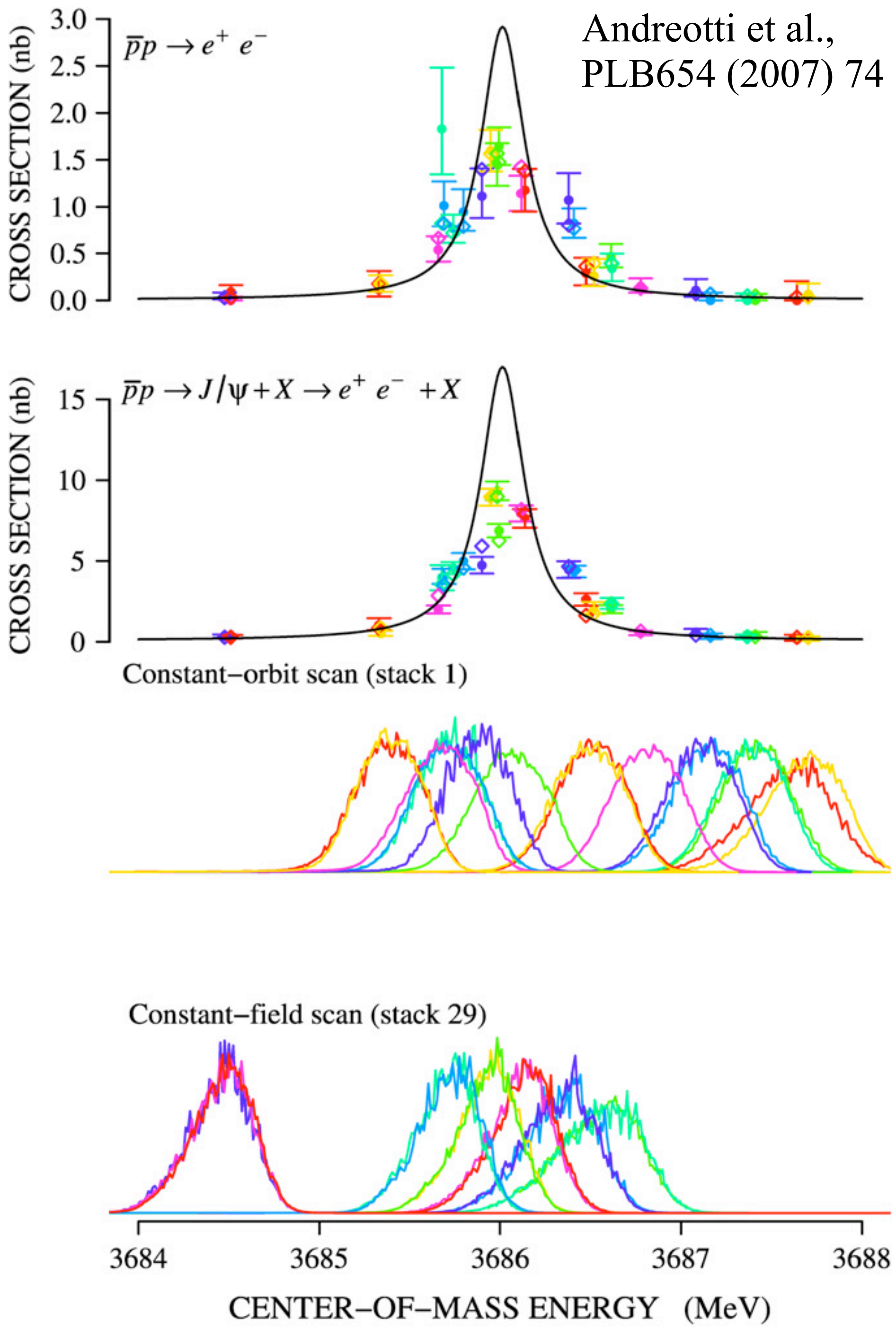


Fig. 2. $\psi(2S)$ resonance scans: the observed cross section for each channel (filled dots); the expected cross section from the fit (open diamonds); the 'bare' resonance curves σ_{BW} from the fit (solid lines). The two bottom plots show the normalized energy distributions B_i.

What Else Can This Do?

Charm!

PHYSICAL REVIEW D **77**, 034019 (2008)

Estimate of the partial width for $X(3872)$ into $p\bar{p}$

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(Received 13 November 2007; published 25 February 2008)

We present an estimate of the partial width of $X(3872)$ into $p\bar{p}$ under the assumption that it is a weakly bound hadronic molecule whose constituents are a superposition of the charm mesons $D^{*0}\bar{D}^0$ and $D^0\bar{D}^{*0}$. The $p\bar{p}$ partial width of X is therefore related to the cross section for $p\bar{p} \to D^{*0}\bar{D}^0$ near the threshold. That cross section at an energy well above the threshold is estimated by scaling the measured cross section for $p\bar{p} \to K^{*-}K^+$. It is extrapolated to the $D^{*0}\bar{D}^0$ threshold by taking into account the threshold resonance in the 1^{++} channel. The resulting prediction for the $p\bar{p}$ partial width of $X(3872)$ is proportional to the square root of its binding energy. For the current central value of the binding energy, the estimated partial width into $p\bar{p}$ is comparable to that of the P-wave charmonium state χ_{c1}.

- Braaten estimate of $\bar{p}p$ $X(3872)$ coupling assuming D^*D molecule
  - extrapolates from K^*K data

Charm!

PHYSICAL REVIEW D **77**, 034019 (2008)

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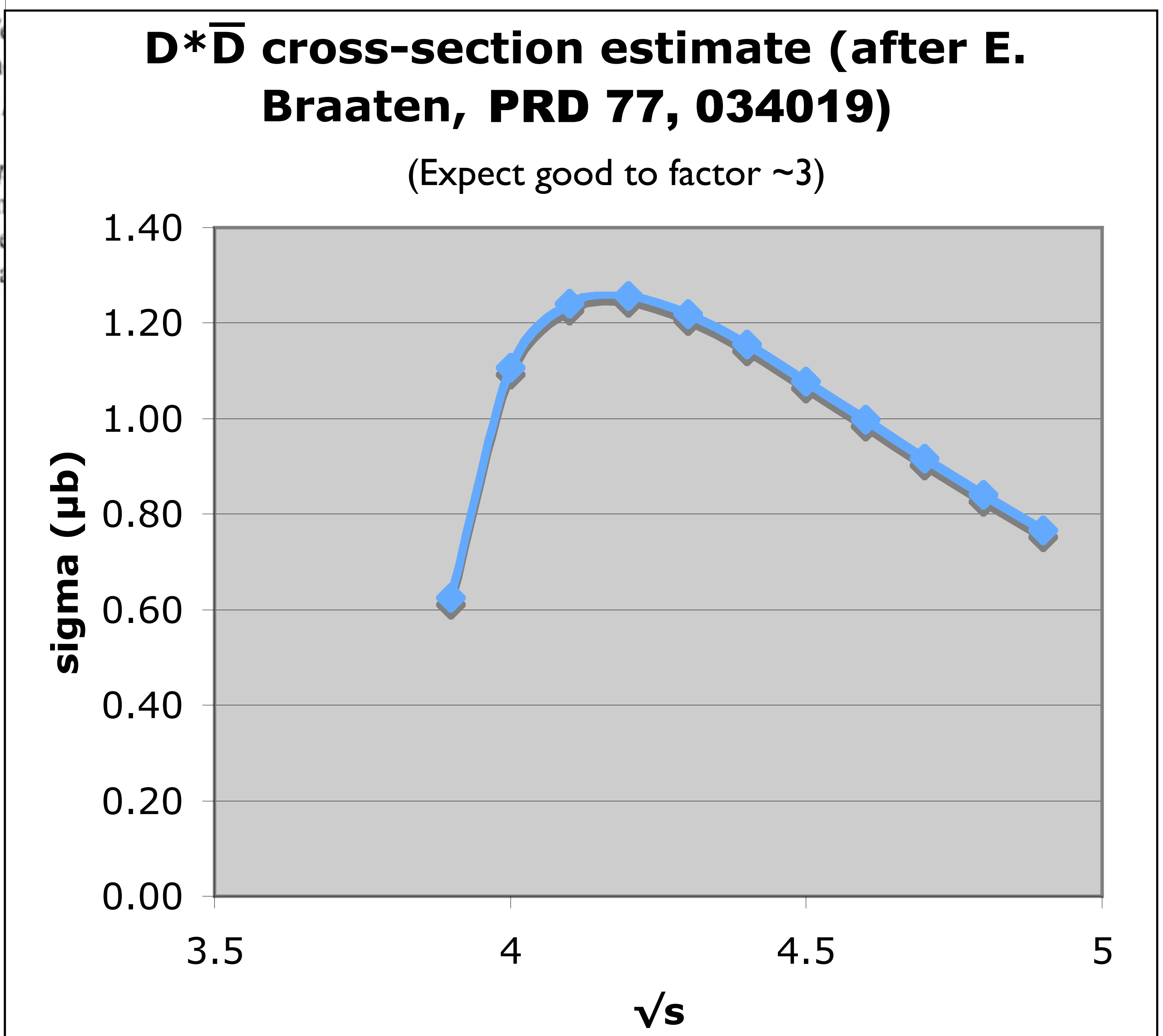
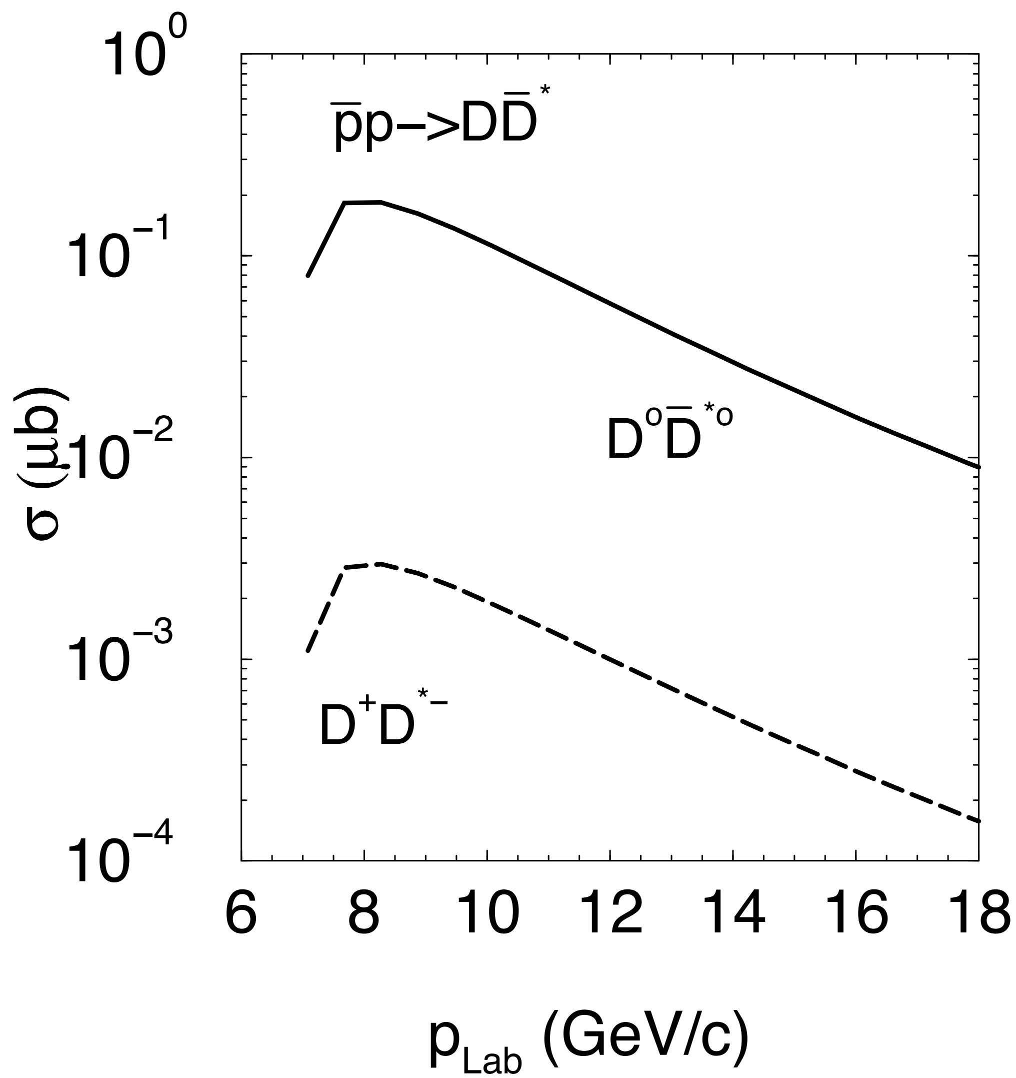


- Braaten estimate of $\bar{p}p$ $X(3872)$ coupling assuming D^*D molecule
  - extrapolates from K^*K data
- By-product is $D^{*0}\overline{D}^0$ cross section
- 1.3 μb → 5 ×10^9/year
- Expect efficiency as at *B* factories

Charm!

- Another approach (Regge model)



A. I. Titov and B. Kämpfer,
Phys. Rev. C **78**, 025201 (2008)

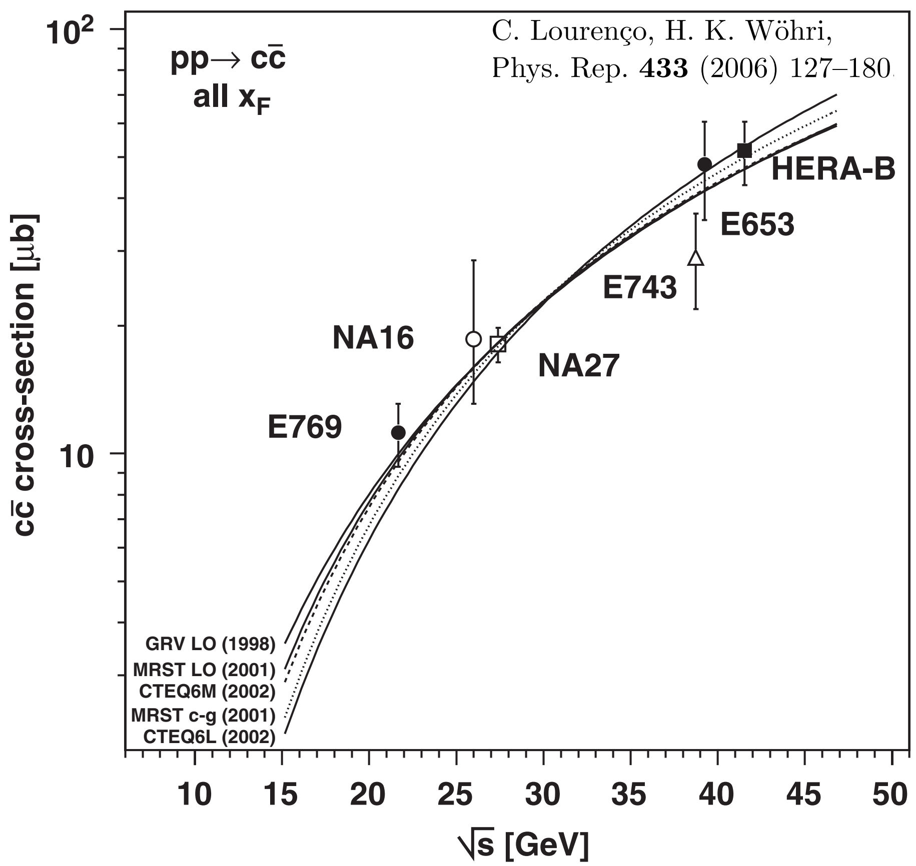
A. Titov, private communication

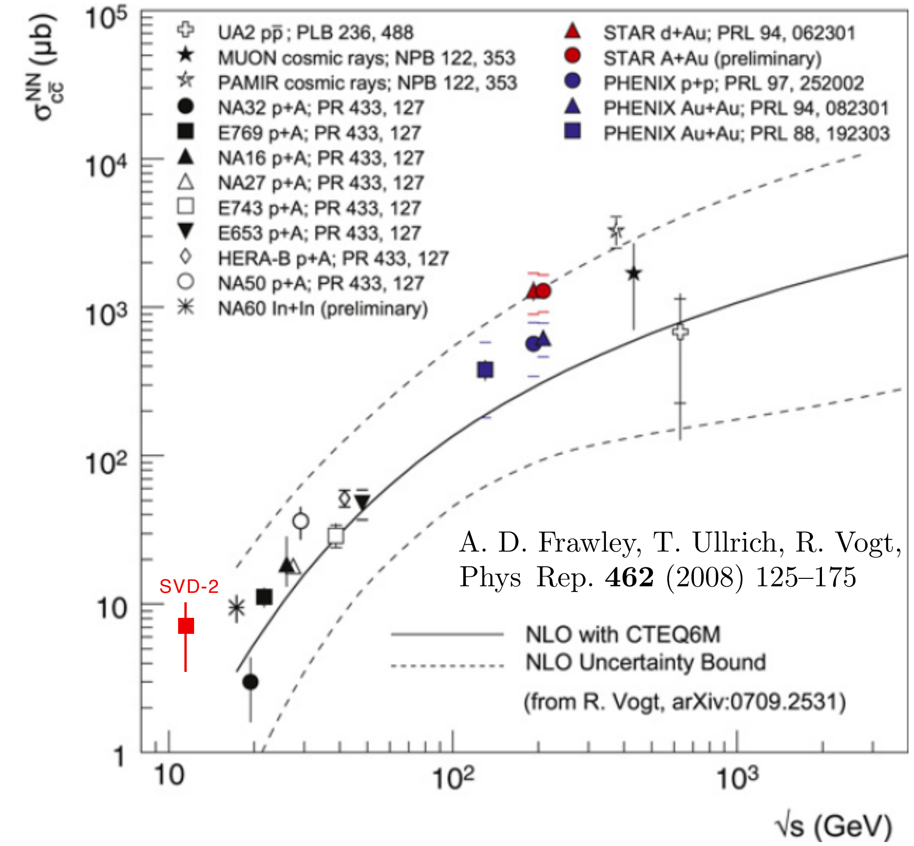
- Agreement within factor of 6

not bad, considering...

Charm!

- Other evidence?





REGISTRATION OF NEUTRAL CHARMED MESONS PRODUCTION AND THEIR DECAYS IN pA-INTERACTIONS AT 70 GeV WITH SVD-2 SETUP

(SVD-2 Collaboration)

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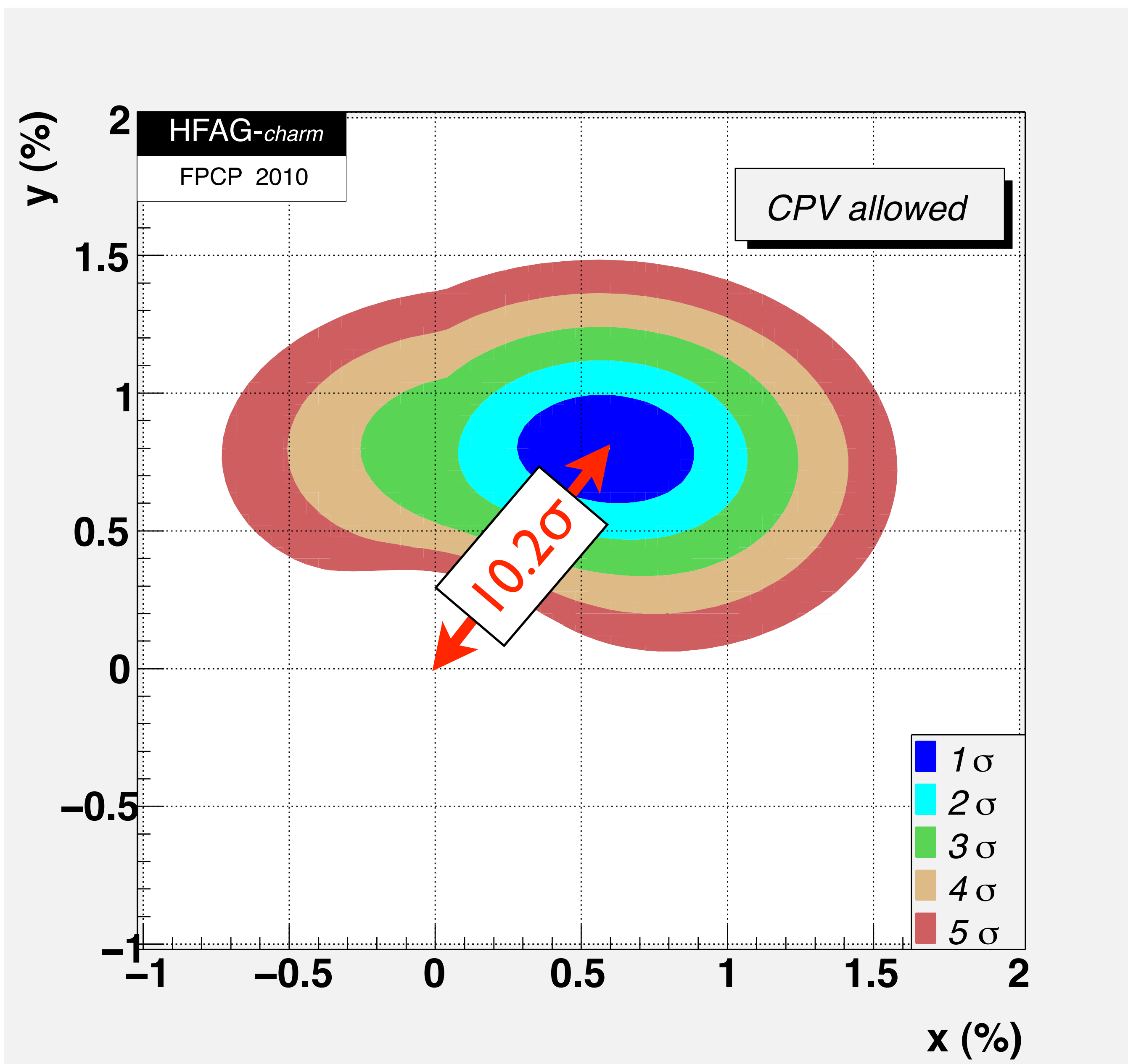
The results of data handling for SERP-E-184 experiment obtained with 70 GeV proton beam irradiation of active target with carbon, silicon and lead plates are presented. Two-prongs neutral charmed D^0 and $\bar{D}^0$ -mesons decays were selected. Signal / background ratio is (51±17) / (38±13). Registration efficiency for mesons was defined and evaluation for charm production cross section at threshold energy is presented: $\sigma(c\bar{c}) = 7.1 \pm 2.4(stat.) \pm 1.4(syst.)$ $(\mu b/nucleon)$.

- Hard to predict size of 8 GeV $\bar{p}$ cross section

⇒Need to measure it!

Charm!

- *What's so exciting about charm?*
  - D^0's mix! (*c* is only up-type quark that can)

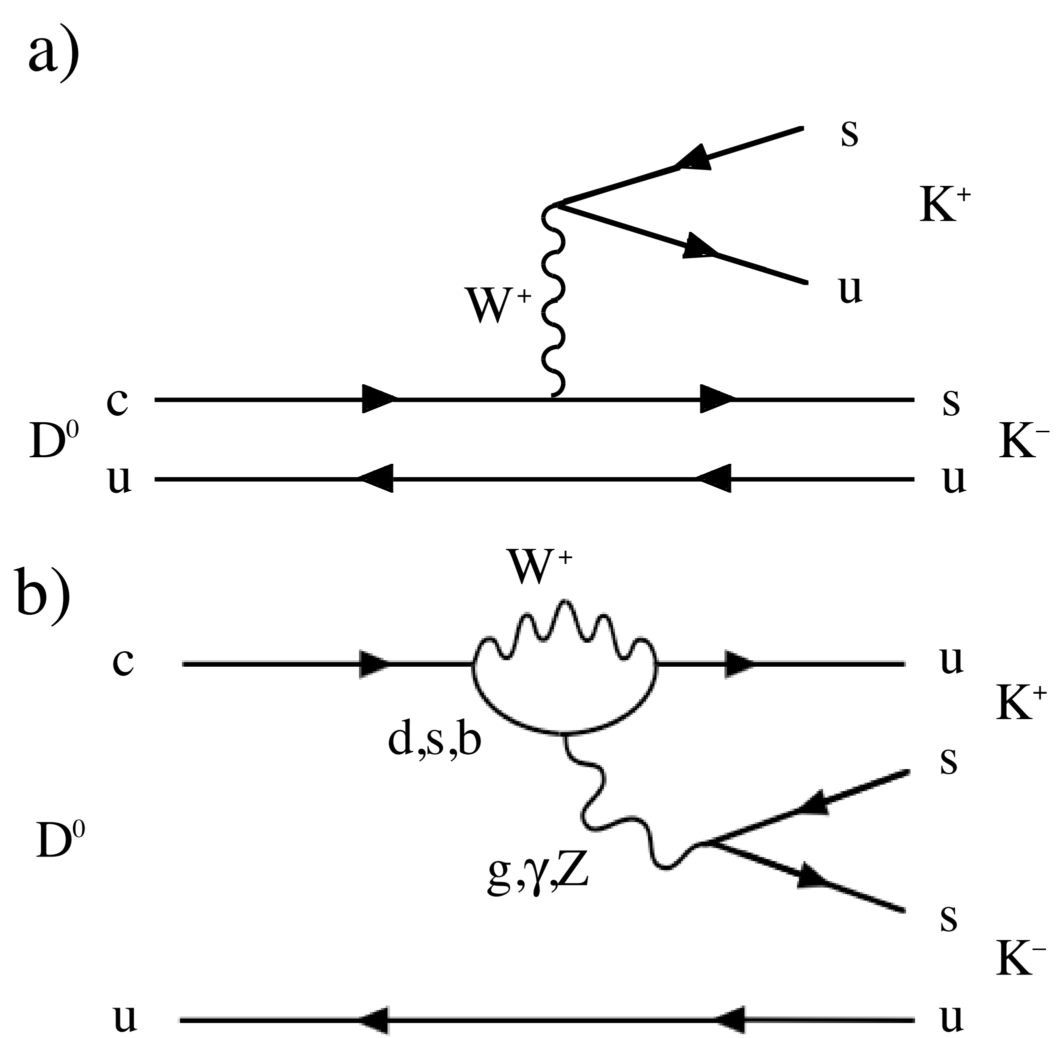


- *Big question:*
  New Physics or old?

Charm!

- *What's so exciting about charm?*
  - *D^0's mix!* (*c* is only up-type quark that can)

Singly Cabibbo-suppressed (CS) *D* decays have 2 competing diagrams:



- *Big question:* New Physics or old?

➡ key is *CP* Violation! Possible in CF, DCS only if New Physics

- B factories have ~10^9 open-charm events
- $\bar{p}p$ may produce >10^{10}/y

➡ world's best sensitivity to charm CPV

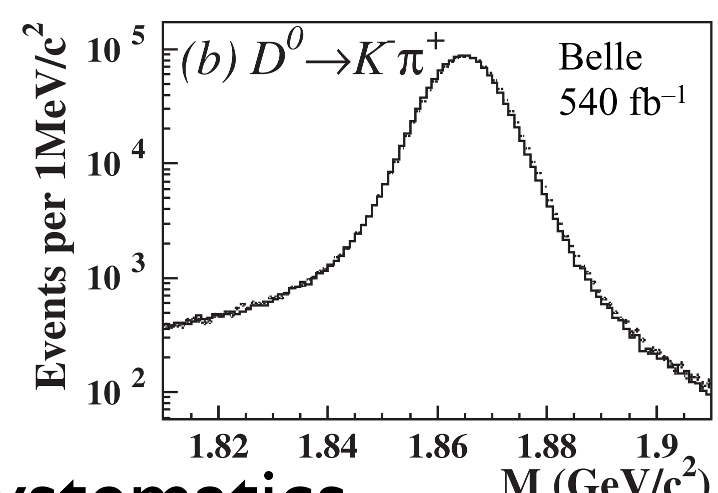
Charm!

- Ballpark sensitivity estimate based on Braaten $\bar{p}p \to D^{*0}\bar{D}^0$ formula, assuming $\sigma \propto A^{1.0}$:

Quantity	Value	Unit
Running time	2×10^7	s/yr
Duty factor	0.8*	
$\mathcal{L}$	2×10^{32}	$\mathrm{cm}^{-2}\mathrm{s}^{-1}$
Annual integrated $\mathcal{L}$	3.2	fb^{-1}
Target A (Ti)	47.9	
$A^{0.29}$	3.1	(based on H.E. fixed-target)
$\sigma(\bar{p}p \to D^{*+} + \text{anything})$	1.25–4.5	μb
# $D^{*\pm}$ produced	$0.3–3 \times 10^{11}$	events/yr
$\mathcal{B}(D^{*+} \to D^0\pi^+)$	0.677	
$\mathcal{B}(D^0 \to K^-\pi^+)$	0.0389	
Acceptance	0.45	(signal MC)
Efficiency	0.1–0.3	(MIPP & bkg MC)
Total	$0.3–3 \times 10^8$	tagged events/yr

*Assumes ≈15% of running time is devoted to antiproton-beam stacking.

- Cf. 1.22 x 10^6 total tagged evts at Belle
[M. Staric et al., PRL **98**, 211803 (2007)]

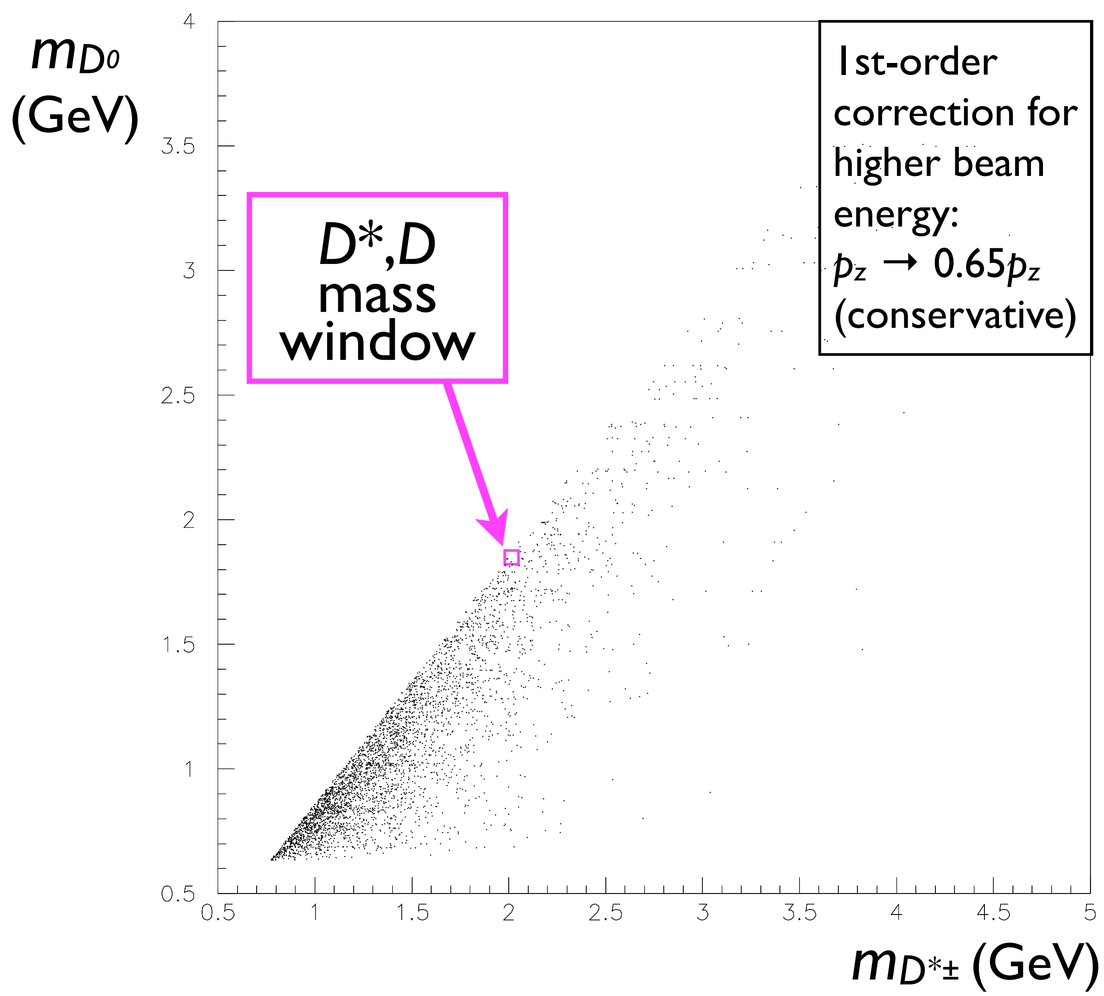


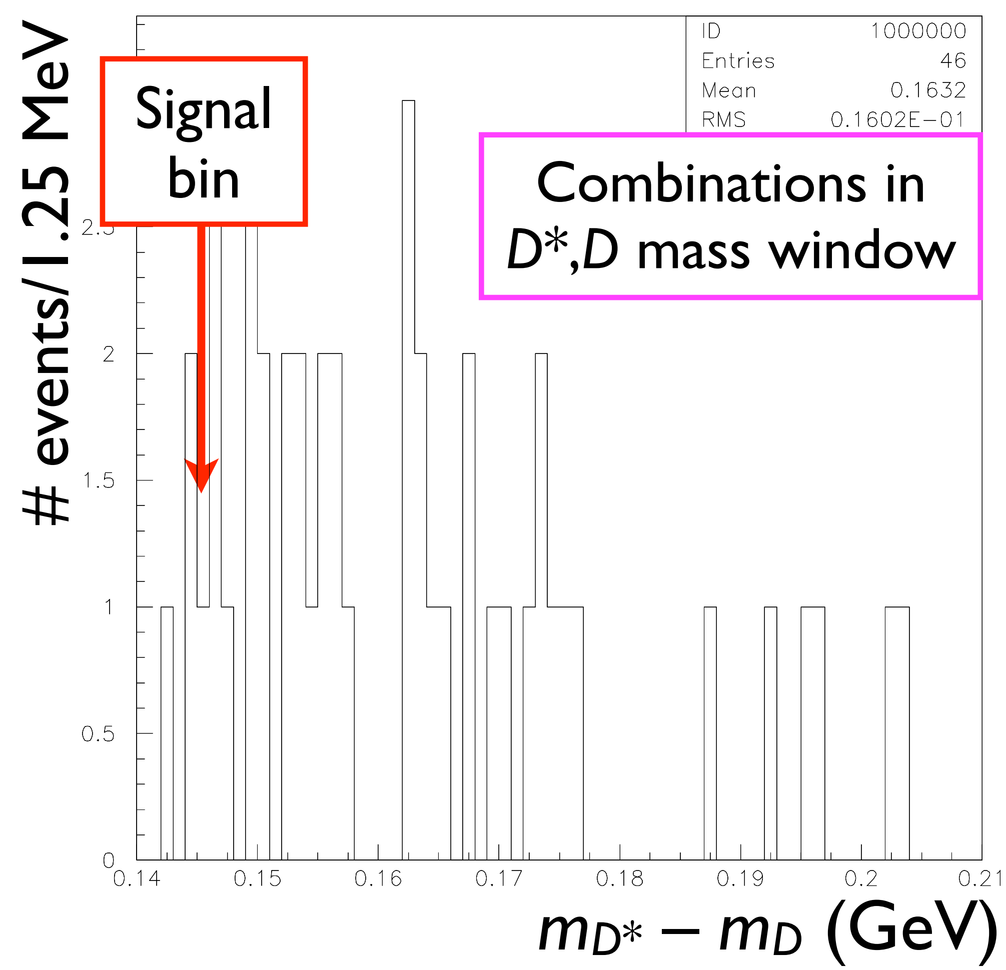
LHC*b* will have comparable statistics but diff't systematics

Competitive with projected ca. 2021 SuperKEKB (5 y @ 10 ab^{-1}/yr)

Background Study

- Study via MIPP 20 GeV $\bar{p}p$ data ($h^{\pm}h^{\mp}h^{\pm}$ events)
- Cut on D^* and D masses and D^*–D mass difference:





- Leaves 1.1±0.3 background events/MeV – *before* kaon ID

Background Study

- MIPP normalization @ 20 GeV not yet worked through in detail, but sample sensitivity ≈ 1 evt/μb
- Say total effective $\sigma(D^{*+})+\sigma(\overline{D}^{*-})$ =

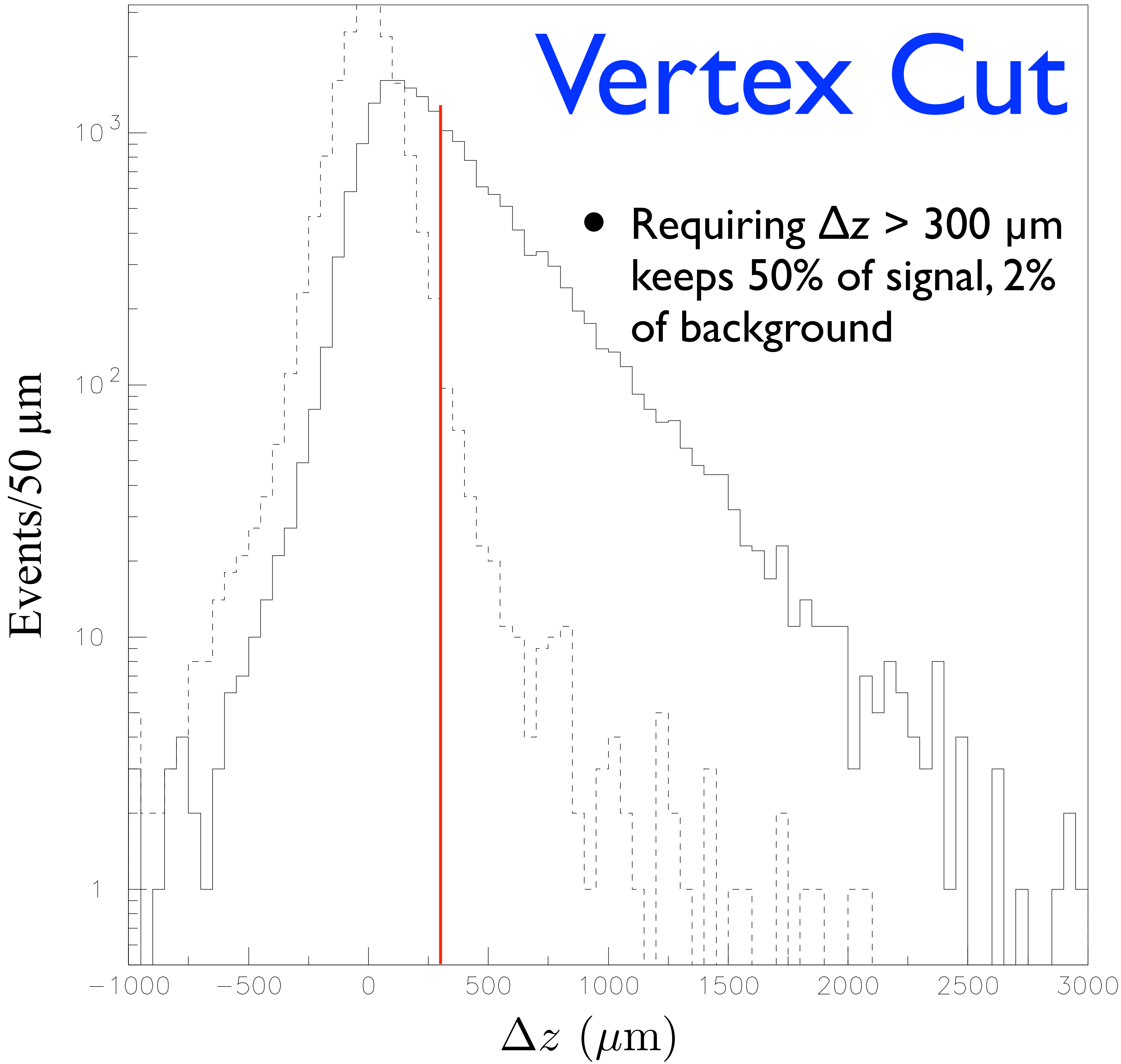
$$2 \times 1.25\ \mu b \times 47.9^{0.29} = 7.7\ \mu b$$

$\times\ \mathcal{B}$: $0.67 \times 0.039 \rightarrow\ \approx 0.2$ evt signal per μb^{-1}

➡ sig/bkg ≈ 0.1 (with above D^*–D cuts)

- Kaon ID → ~ x 30 ⇒ sig/bkg ≈ 3
- Lifetime cuts → e.g. x 50 @ 50% effic.

Vertex Cut



- Requiring Δz > 300 μm keeps 50% of signal, 2% of background

Background Study

- MIPP normalization @ 20 GeV not yet worked through in detail, but sample sensitivity ≈ 1 evt/μb
- Say total effective $\sigma(D^{*+})+\sigma(\overline{D}^{*-})$ =

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- Kaon ID → ~ x 30 ⇒ sig/bkg ≈ 3
- Lifetime cuts → e.g. x 50 @ 50% effic.

⟹ Clean sample (sig:bkg ~ 100:1) can be obtained with reasonable (>0.1) efficiency

Breadth of Program

- Partial list of physics papers/thesis topics:

General	
1	Particle multiplicities in medium-energy pbar-p collisions
2	Particle multiplicities in medium-energy pbar-N collisions
3	Total cross section for medium-energy pbar-p collisions
4	Total cross section for medium-energy pbar-N collisions
Charm	
5	Production of charm in medium-energy pbar-p collisions
6	Production of charm in medium-energy pbar-N collisions
7	A-dependence of charm production in medium-energy pbar-N collisions
8	Associated production of charm baryons in medium-energy pbar-N collisions
9	Production of charm baryon-antibaryon pairs in medium-energy pbar-N collisions
10	Measurement of D0 mixing in medium-energy pbar-N collisions
11	Search for/Observation of CP violation in D0 mixing
12	Search for/Observation of CP violation in D0 decays
13	Search for/Observation of CP violation in charged-D decays
Hyperons	
14	Production of Lambda hyperons in medium-energy pbar-p collisions
15	Production of Sigma0 in medium-energy pbar-p collisions
16	Production of Sigma- in medium-energy pbar-p collisions
17	Production of Xi- in medium-energy pbar-p collisions
18	Production of Xi0 in medium-energy pbar-p collisions
19	Production of Omega- in medium-energy pbar-p collisions
20	Production of Lambda Lambdabar pairs in medium-energy pbar-p collisions
21	Production of Sigma+ Sigmabar- pairs in medium-energy pbar-p collisions
22	Production of Xi- Xibar+ pairs in medium-energy pbar-p collisions
23	Production of Omega- Omegabar+ pairs in medium-energy pbar-p collisions
24	Rare decays of Sigma+
25	Rare decays of Xi-
26	Rare decays of Xi0
27	Rare decays of Omega-
28	Search for/Observation of CP violation in Omega- decay
Charmonium	
29	Production of X(3872) in medium-energy pbar-p collisions
30	Precision measurement of X(3872) mass, lineshape, and width
31	Decay modes of X(3872)
32	Limits on rare decays of X(3872)
33	Production of other XYZ states in medium-energy pbar-p collisions
34	Precision measurement of the eta_c mass, line shape and width
35	Precision measurement of the h_c mass, line shape and width
36	Precision measurement of the eta_c' mass, line shape and width
37	Complementary scans of J/psi and psi'
38	Precise determination of the chi_c COG
39	Production of J/psi and Chi_cJ in association with pseudoscalar meson(s)

- Participation in TAPAS could ease transition to the intensity frontier for some Tevatron scientists

Cost Estimate

- Extensive availability of highly capable equipment makes this effort highly cost-effective:

Item	Cost (k$)	Contingency (k$)
Targets	430	160
Luminosity monitor	60	20
Scintillating-fiber tracking system	1,820	610
Time-of-Flight system*		
Triggering	1,390	460
Data acquisition system	490	153
Infrastructure	1,350	550
TOTALS	5,540	1,950

- Uses existing Antiproton Source (but not Recycler), calorimeter, solenoid, SciFi readout system, trigger & DAQ electronics

Cost Estimate

- Note: We seek to fund most of this via university grants

➡ including substantial engineering & technician effort, e.g...

Table 13: SciFi Budget Estimate.

Type	Number	Cost (k$)	Cont'cy (k$)	Basis
Scintillating fiber	90 km	40	20	Kuraray (MICE quote)
Clear fiber	300 km	280	140	Kuraray (MICE quote)
Engineering effort	2 FTE-yr	500	150	MICE
Technician effort	6 FTE-yr	600	200	MICE
Fiber mirroring		100	25	MICE
Optical connectors		200	50	MICE
Support structure		100	25	MICE
TOTALS		1,820	610	

(plus the usual postdocs & students)

Impact on Other Expts

- Uses only 2% of MI protons
  - compatible with 700 kW beam power to NOνA
- Incompatible with $g - 2$ @ Antiproton Source
  - but alternative $g - 2$ siting available @ B0
- Incompatible with mu2e @ Antiproton Source
  - but we can be done in time for mu2e

0^{th}-order run-plan example:

install/debug	~6 mo
find $X(3872)$	~1 mo
measure $\sigma(D^*)$	~1 mo
measure $\sigma(\Omega\bar{\Omega})$	~1 mo
charmonium	~1 mo
$X(3872)$ run	~12 mo
hyperon CP run	~12 mo
install/debug hadron-ID upgrade	~3 mo
charm CP run	~12 mo

if σ's favorable

- Our request:
  - Scientific approval so that we can submit grant proposals to fund the effort

Summary

- Best experiment ever on hyperons, charm, and charmonia may soon be feasible at Fermilab
  - possibly world's most sensitive study of charm mixing, CPV, & rare decays
- Existing equip't enables quick, cost-effective effort
  - could start data-taking by 2014 (or 2015 if 3-yr Tevatron ext.)
- Mix of speculative and established physics goals
  - for some, feasibility depends on poorly known cross sections
  - we can measure them quickly and cost-effectively
  - no modification of accelerator complex required
- World's best $\bar{p}$ source $\rightarrow$ simple way to broad physics program in pre-Project X era

Backup

- Some Hyperon CPV references:

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Table 11: Target Budget Estimate.

Type	Cost (k$)	Cont'cy (k$)	Basis
Wire	30	10	
Solid hydrogen	400	150	S. Ishimoto, KEK
TOTALS	430	160	

Table 12: Luminosity Monitor Budget Estimate.

Item	Cost (k$)	Cont'cy (k$)	Basis
Scintillation telescope	50	15	
Electronics	10	5	
TOTALS	60	20	

Table 13: SciFi Budget Estimate.

Type	Number	Cost (k$)	Cont'cy (k$)	Basis
Scintillating fiber	90 km	40	20	Kuraray (MICE quote)
Clear fiber	300 km	280	140	Kuraray (MICE quote)
Engineering effort	2 FTE-yr	500	150	MICE
Technician effort	6 FTE-yr	600	200	MICE
Fiber mirroring		100	25	MICE
Optical connectors		200	50	MICE
Support structure		100	25	MICE
TOTALS		1,820	610	

Table 15: Trigger Systems Budget Estimate.

Item	Number	Unit cost (k$)	Cost (k$)	Cont'cy (k$)	Basis
Level 1*					P. Rubinov, FNAL
L2 Compute Nodes	100	9	900	300	P. Rubinov, FNAL
L2 Farm nodes	50	2	100	30	
Postdoc effort	3 FTE-yr		270	90	
Student effort	3 FTE-yr		120	40	
TOTALS			1,390	460	

*Level 1 trigger from DØ.

Table 16: Data Acquisition Budget Estimate.

Item	Number	Unit cost (k$)	Cost (k$)	Cont'cy (k$)	Basis
Calorimeter flash ADC	1,200	0.10	120	30	P. Rubinov, FNAL
VME system*	TBD	0	0	0	
Data buffering system	1		10	3	M. Crawford, FNAL
Tape drive+host node	5	18	90	30	M. Crawford, FNAL
Postdoc effort	2 FTE-yr		180	60	
Student effort	2 FTE-yr		90	30	
TOTALS			490	153	

*Available from CDF and DØ.

Table 17: Infrastructure Budget Estimate.

Item	Cost (k$)	Cont'cy (k$)	Basis
Assemble and install solenoid flux return	300	100	Vl. Kashikhin, FNAL
Cryogenics & solenoid installation	900	400	M. Green, LBNL, R. Rucinski, FNAL
Install Be beam pipe	50	20	
Install cables	100	30	
TOTALS	1,350	550	

Table 18: Estimate of Annual Operating Costs.

Item	#/yr	Unit cost	Cost (k$)	Cont'cy (k$)	Basis
Antiproton Source operations			2,000		K. Gollwitzer, FNAL
Magnetic tapes	1000	35	35	35	M. Crawford, FNAL
Tape libraries	0.1	700k	70	70	M. Crawford, FNAL
Equipment maintenance			10	10	
TOTALS			2,115	115	

$\bar{p}$ Charm Factory?

- Another possibility (E. Braaten): use the $X(3872)$ as a pure source of $D^{*0}\bar{D}^0$ events
  - the $\bar{p}p$ equivalent of the $\psi(3770)$!?
  - assuming current Antiproton Accumulator parameters ($\Delta p/p$) & Braaten estimate, produce ~10^8 events/year
  - comparable to BES-III statistics
  - could gain factor ~5 via AA e^- cooling?
- Proposed expt will establish feasibility & reach

International Aspect

- Potential European interest (e.g. $\overline{\text{P}}$ANDA, Saclay, etc.)
  - early data & experience for $\overline{\text{P}}$ANDA collaborators
- Also possible interest at Academia Sinica, Taiwan
- Could significantly reduce needed US resources
- But recent US HEP events cautionary

➡ need indication of US interest to begin negotiation

P̄ANDA

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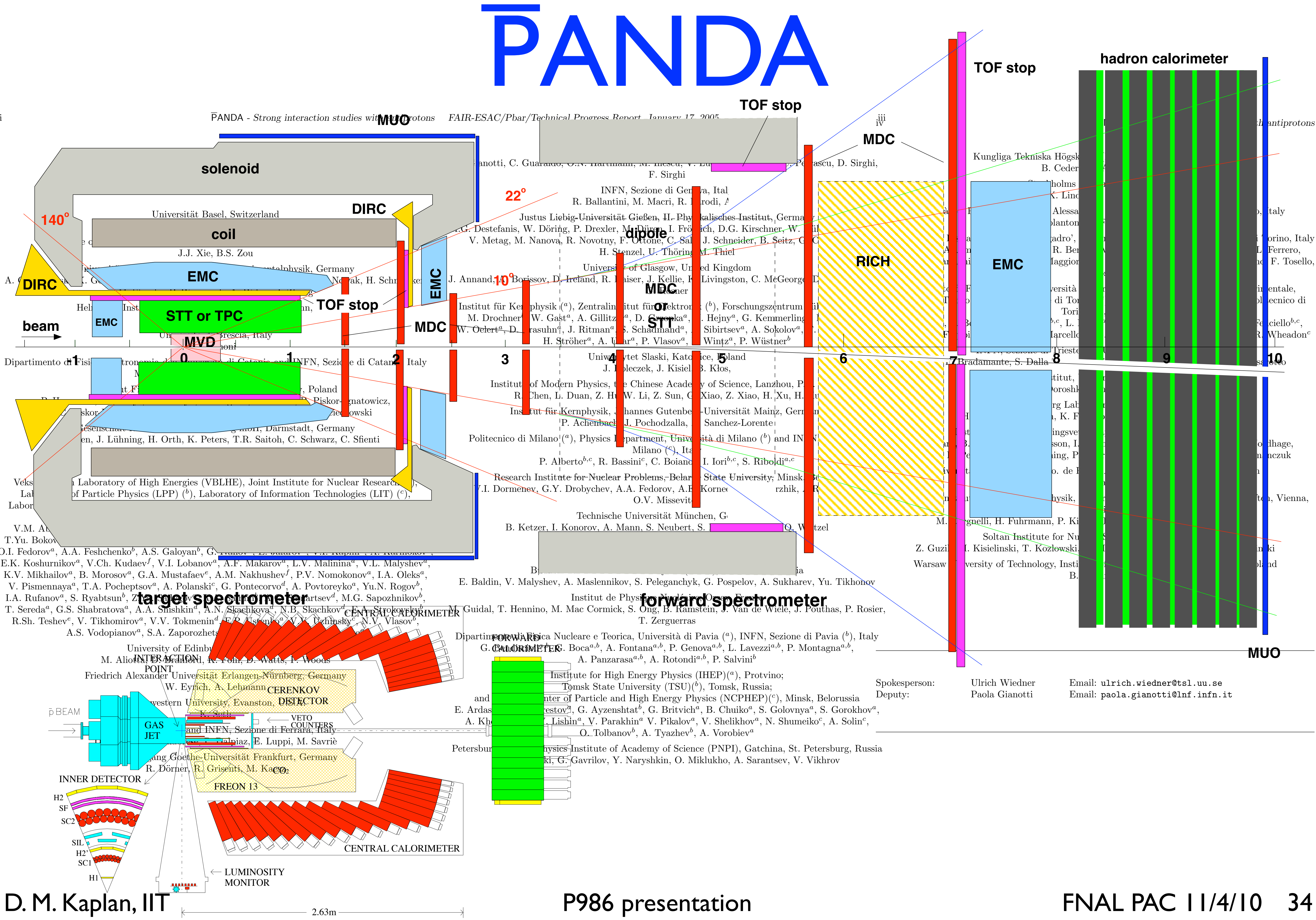
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GAS JET
p̄ BEAM
INNER DETECTOR
FREON 13
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2.63m
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$\overline{\text{P}}$ANDA Physics Topics

- Charmonium ($c\bar{c}$) spectroscopy (mass, widths, branching ratios)
- Establishment of the QCD-predicted gluonic excitations (charmed hybrids, glueballs) in the 3–5 GeV/c^2 mass range
- Search for modifications of meson properties in the nuclear medium
- Precision γ-ray spectroscopy of single and double hypernuclei
- Extraction of generalized parton distributions from $\bar{p}p$ annihilation
- *D* meson decay spectroscopy (rare decays)
- Search for CP violation in the charm and strangeness sector

Some HyperCP Publications:

- L. C. Lu *et al.*, "Measurement of the asymmetry in the decay $\overline{\Omega}^+ \to \overline{\Lambda} K^+ \to \overline{p}\pi^+ K^+$," Phys. Rev. Lett. **96**, 242001 (2006).
- D. Rajaram *et al.*, "Search for the Lepton-Number-Violating Decay $\Xi^- \to p\mu^-\mu^-$," Phys. Rev. Lett. **94**, 181801 (2005).
- C. G. White *et al.*, "Search for Delta $\Delta S = 2$ Nonleptonic Hyperon Decays," Phys. Rev. Lett. **94**, 101804 (2005).
- H. K. Park *et al.*, "Evidence for the Decay $\Sigma^+ \to p\mu^+\mu^-$," Phys. Rev. Lett. **94**, 021801 (2005).
- M. Huang *et al.*, "New Measurement of $\Xi^- \to \Lambda\pi^-$ Decay Parameters," Phys. Rev. Lett. **93**, 011802 (2004);
- M. J. Longo *et al.*, "High-Statistics Search for the $\Theta^+(1.54)$ Pentaquark," Phys. Rev. D **70**, 111101(R) (2004);
- T. Holmstrom *et al.*, "Search for *CP* Violation in Charged-Ξ and Λ Hyperon Decays," Phys. Rev. Lett. **93**, 262001 (2005);
- Y. C. Chen *et al.*, "Measurement of the Alpha Asymmetry Parameter for the $\Omega^- \to \Lambda K^-$ Decay," Phys. Rev. D **71**, 051102(R) (2005);
- L. C. Lu *et al.*, "Observation of Parity Violation in the $\Omega^- \to \Lambda K^-$ Decay," Phys. Lett. B **617**, 11 (2005).
- R. A. Burnstein *et al.*, "HyperCP: A High-Rate Spectrometer for the Study of Charged Hyperon and Kaon Decays," Nucl. Instrum. Methods A **541**, 516 (2005).
- O. Kamaev *et al.*, "Study of the Rare Hyperon Decay $\Omega^\mp \to \Xi^\mp \pi^+\pi^-$," Phys. Lett. B **693** (2010) 236.